E/CONF.39/A/310
1 Nov.1962
ORIGINAL : ENGLISH

UNITED NATIONS CONFERENCE
ON THE APPLICATION OF SCIENCE AND TECHNOLOGY
FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

Agenda Item: A.4.2.4

United States of America

METALLURGICAL, DOMESTIC AND INDUSTRIAL UTILIZATION OF LOW-RANK COALS

By W.S. LANDERS,
Chief,
Denver Coal Research Laboratory,
Division of Bituminous Coal,
Bureau of Mines,
U.S. Department of the Interior,
Denver, Colorado, U.S.A

Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

NOTES

1. Papers selected for inclusion in General Sessions will be available at the Conference in the following official languages of the United Nations: English, French, Russian and Spanish.

2. Papers selected for inclusion in Specialized Sessions will be available at the Conference in only one of the above official languages.

3. Summaries of all papers, as submitted by contributors, will be available at the Conference in the following official languages of the United Nations: English, French, Russian and Spanish.

4. Papers and summaries will not be available for general distribution in advance of the Conference. They will be published in advance in limited quantities only for the use of delegations of participating governments and of other authorized participants. Post-Conference publication and general distribution of the Conference Proceedings will follow United Nations practices as laid down by the United Nations Publications Board.

METALLURGICAL, DOMESTIC, AND INDUSTRIAL UTILIZATION OF LOW-RANK COALS

by

W. S. Landers,
Chief, Denver Coal Research Laboratory, Division of Bituminous Coal,
Bureau of Mines, U. S. Department of the Interior,
Denver, Colorado, U. S. A.

1. The proper utilization of coal resources is an important, and possibly essential, step in the advancement of less developed areas of the world. Coal is a widely distributed mineral, usually comprising a significant potential source of energy and chemicals where the reserves of coal are adequate and where it can be economically mined. The low-rank coals of the world are widely distributed; but their utilization, particularly in expanding economies of the less developed areas, has been restricted, because of their chemical and physical properties. Low-rank coals for the present purpose include brown coals, lignites, and subbituminous coals, corresponding to classes 10 through 15 of the International system for classifying brown coals and lignites. They are all characterized by high moisture content, a relatively low heating value, high oxygen content, inability to fuse to produce coke, and high susceptibility to spontaneous combustion during transportation or storage.

2. In less developed areas of the world, the major historical usage of low-rank coals has been as fuel for local consumption. Even this restricted use, however, has been difficult in many areas because these coals cannot be burned successfully and easily in equipment used with wood, charcoal, and other traditional fuels. The purpose of this paper is to present and discuss techniques applicable in these areas that would permit the extension of the use of such coals as technologic and industrial development progresses. Within the space limitations of this paper, it will not be possible to do more than suggest or mention many of the possible areas and techniques of utilization. It is my intent, however, to show that widespread application can be made of such fuels through the use of technologies and information now available.

3. Coal utilization may best be discussed under several general categories. I have chosen to emphasize the application of low-rank coals to iron ore reduction because of the widespread international importance of metallurgy and the projected expansion of the steel industry in the less developed areas of the world.

4. Since prehistoric times, metallurgical operations have used charcoal or anthracite as a source of heat and as a chemical reducing agent. These fuels, however, are too costly or do not possess the proper physical or chemical properties for use in modern, large-scale metallurgical operations. As the need for stronger, cheaper, and more uniform fuels developed for these applications, the metallurgical industry concentrated in those areas of the world having coking coals. Small local metallurgical industries persist to this day in countries not so fortunately endowed, but such installations are not adequate to serve the needs of an expanded industrial economy.

5. The most intriguing, useful, and desirable metallurgical application of coal in our present economy is in the production of pig iron. The blast furnace is used almost universally, in one way or another, to produce this material. Because of the requirements of the blast furnace, the fuel supplied to modern units is a strong, hard coke, containing low concentrations of water and volatile matter. Low-rank coals do not possess the property of directly fusing in the coke oven to form such a coke. If they are charged in their natural state as a coke substitute, the blast furnace cannot function because the coals, in addition to having a high volatile matter content, will crumble and clog the passage of the air blast. However, recent developments have demonstrated two processes by which pig iron can be produced with noncoking coals. The first of these is the modification, through suitable processing, of the low-rank coals to form a synthetic coke that can be charged as part of the burden in conventional or modified blast furnaces. The second approach is the utilization of metallurgical techniques not requiring the use of the blast furnace. It is not the purpose of this paper to discuss the relative merits of these two techniques, as the choice between them transcends technologic consideration.

6. The production of synthetic coke by modification of low-rank coals consists basically in changing the chemical structure of the coal to reduce its moisture, oxygen, and volatile matter contents, to increase its fixed carbon content and heating value, and to consolidate the modified coal into a strong, dense agglomerate. The FMC Corporation and the United States Steel Corporation, both of the United States, have recently developed and announced a process to accomplish these results. This process, generally known as the "FMC Process", consists of the following steps:

(a) Stage crushing of the coal to less than 1/8 inch (3.2 mm).

(b) Preprocessing of the crushed coal by controlled oxidation at a relatively low temperature in a fluidized bed in order to modify both chemical and physical nature of the coal.

(c) Carbonization of the modified coal in a fluidized bed to produce a low-temperature char (semicoke) and sufficient condensable tar for use in the subsequent briquetting operation.

(d) Production of a low-volatile char by recarbonization of the low-temperature char at high temperatures in a fluidized bed.

(e) Briquetting of the high-temperature char with the entire output of low-temperature tar in conventional, high-pressure, opposed-roll presses.

(f) Controlled oxidation at moderate temperatures in a shaft furnace to modify the chemical nature of the tar binder.

(g) Recarbonization of the modified briquets at high temperatures to produce a strong, low-volatile matter briquet suitable for blast furnace and other metallurgical applications.

A comparison of the physical properties of large size FMC Process briquets and similar properties of conventional foundry coke is given in table 1 (see annex). The FMC briquets may be made in any size, and it has been indicated that reactivity and other properties of the briquets can be controlled by selection of temperature, residence time, and other operating variables.

7.. Brown coal and lignite have effectively been converted in various parts of the world to materials suitable for use in low-shaft furnaces. Many of these low-rank coals are briquettable in high pressure equipment without the use of binders. This technique, where applicable, requires crushing and drying of the high-moisture lignite or brown coal to a preestablished optimum moisture content, briquetting in high pressure equipment, and carbonization of the briquets to high temperatures to produce a low volatile coke. The heating schedule for the carbonization is critical, but an excellent product can be obtained by this technique. For those lignites and brown coals not briquettable without a binder, briquets can be produced from either the dried or carbonized coal using pitch or other binders. Such briquets are usually carbonized to produce a low-volatile, hard coke. If high density fuels are not required, it is possible to pelletize coal with suitable binders and to carbonize the pellets by a carefully controlled heating schedule in a stream of hot natural gas or methane. This treatment sets the aggregate into a strong cokelike structure.

8. The other major approach to the utilization of low-rank fuels in the production of pig iron involves the use of techniques not requiring the blast furnace. There are a variety of such "direct reduction" processes that have either been tried or suggested, but most of them make use of an inclined rotary kiln into which a burden of ore, flux, and solid fuel is charged. As the burden moves through the kiln, some of the fuel burns in the air blast introduced at the discharge end to produce the heat required for the reactions; the remainder of the fuel then acts as a chemical reducing agent to produce metallic iron (or partially reduced iron oxides) from the oxide ores. There are many variations possible in this approach. For example, some processes produce a molten slag of vitreous material in which the iron particles are suspended. The slag issuing from the kiln is quenched and crushed, and the iron particles are collected by gravity separation or by magnetic means. In other processes, the kiln is operated under nonslagging conditions producing either finely divided metallic iron distributed throughout the nonfused product, partially reduced iron ore, or a mixture of the two.. It has been successfully demonstrated that char or semicoke made by the carbonization of low-rank coals is a satisfactory fuel for use in direct reduction kilns. These chars, generally produced in entrained or fluidized beds, are highly reactive, and if formed at the proper temperature, they do not produce any objectionable tars or liquids that could affect the operation of the necessary dust collecting apparatus used at the gas discharge end of the kiln. It has also been demonstrated that raw lignite can be used efficiently as the reducing agent in at least one of the direct reduction operations. It is likely that, through suitable modification of operating techniques, raw, dried or carbonized lignite, brown coals, and subbituminous coals can be used in a variety of the direct reduction processes.

9. The use of low-rank coals in the production of pig iron can be accomplished, then, through either the radical modification of the coal to produce a synthetic cokelike material that can be used in the blast furnace or the application of direct reduction kilns with either raw or modified noncoking coals as the fuel. The choice between these two approaches is an extremely complex one, depending upon quality and physical structure of the ore, as well as upon economic and other technological considerations.

10. Other metallurgical processes, such as scrap melting, slag reprocessing, and reduction of nonferrous metals, can utilize the coke substitutes prepared from the low-rank coals. These coke substitutes can also replace coke in other industries; for example, FMC Process briquets have been used in electric furnaces producing elemental phosphorous.

11. Sources of adequate fuel for domestic heating and cooking are becoming increasingly important problems in many of the less developed areas of the world. The fuels frequently used in these areas are wood , charcoal, and dried dung. The source of wood and charcoal has been the forests contiguous to centers of population, and a natural balance has been effected over the centuries between the use of the wood and the rate of growth of the forests. In recent years, however, such balances have been upset in many places by the rapidly increasing population. The forests are being depleted, the source of wood is receding from the population centers, and the cost of wood or charcoal is increasing rapidly. Raw low-rank coals can be used effectively for cooking and heating; however, it is necessary to have stoves and furnaces specifically adapted to the burning of high moisture solid fuels. Such equipment is not readily available in the less developed areas of the world. In addition, there are established techniques of cooking and heating based upon the traditional fuels available in these areas. Eventually, it might be possible to modify the habits of the inhabitants of these areas so that the coals can be burned directly in proper stoves and furnaces, but this will be a slow process. The better solution, and one more likely of immediate acceptance, is to modify the low-rank coals by processing so that the resulting products can be burned in braziers and other existing equipment in the traditional manner.

12. Let us examine the properties of the traditional fuels and compare them with the equivalent properties of the low-rank coals. Wood is an easily stored, easily ignited fuel requiring no special equipment for its handling or use. When it burns, however, it produces a smoky flame with an acrid odor. As a consequence of this smokiness, the practice has developed in many villages and towns of burning charcoal. Charcoal is also an easily ignited, handled, and stored fuel. It burns without odor or smoke and is well suited for use in populated areas and in kitchen stoves not equipped with flues or smoke stacks. Dried cow- or water-buffalo-dung is easily stored and ignited. While it burns with a distinctive odor, it does give a smokeless flame and is an extensively used fuel. All three of these fuels are easily handled and consist of relatively large size particles that can be burned in simple equipment with little difficulty in providing adequate draft. When the immediate use is complete, the remaining fuel can be extinguished with water, allowed to sun dry, and later reignited and used until it is completely consumed.

13. The low-rank coals, on the other hand, are characterized by high moisture content. Lump low-rank coal will slack and degrade to fine sizes or powder as the natural moisture in the coal evaporates if it is stored by simply piling or stacking. The resulting powder, or dust, is not suitable for burning in braziers.

If the coal lumps are charged while they are fresh, that is, with their full moisture content, they are very difficult, if not impossible, to ignite in such equipment. As the lumps become heated in the fire, they dry and disintegrate, producing powder which chokes the fuel bed and prevents combustion. It is almost impossible to quench and recover unburned lumps from a fuel bed prepared from low-rank coals.

14. The problem, then, is to convert the coal into materials having properties as similar as possible to the preferred fuels. The general approach is to briquet the coal. Some of the low-rank coals can be crushed, dried to an optimum moisture content of about 10 to 16 percent, and briquetted without binder in high-pressure extrusion presses. The resultant briquets are then carbonized, converting the coal into a smokeless, easily ignited, free burning char or semicoke briquet. The carbonized briquets are relatively porous and are reactive enough to be ignited by the same procedure used by the housewife for igniting charcoal.

15. If the coal cannot be briquetted without binder, an additive must be used to provide the cohesiveness necessary to form briquets. Such coals are carbonized to eliminate moisture and reduce the volatile matter content, and the char is briquetted with a suitable binder. Starch, molasses, kraft paper waste, portland cement, clay, and other binders have successfully been used for this purpose. Excellent binders are pitches and asphalts. These latter materials coke when heated and form an extremely strong matrix, giving coherence to the briquet in the fuel bed. However, they burn with a smoky flame, and it is generally preferable to recarbonize these briquets before use in open domestic appliances. The problem of odor occurring during the burning of carbonized coal briquets made from char and tar has become important in the United States because of the use of such briquets for outdoor cooking. One of the major producers of carbonized coal briquets in the United States has effectively eliminated such odor through proper cooling of the char and briquets, and by the addition of small quantities of additives and catalysts. These briquets are finding wide acceptance as a premium domestic fuel.

16. One of the largest and most important uses of coal in the less developed areas of the world will probably be in thermal power plants. It has been adequately demonstrated that any of the low-rank coals can be burned efficiently in modern equipment, and the use of coal is primarily determined on the basis of economics. Small power plants can burn the coal on spreader or traveling-grate stokers, or the coal may even be hand-fired. Larger plants will probably use pulverized fuel burners. High-moisture coal must either be partially dried or very finely ground before it enters the pulverized fuel burners. The modern approach is to partially dry the coal, either by using hot-gas-swept pulverizing mills or by predrying the coal before pulverizing. Large power generating plants in the United States using lignite with 35- to 45-percent moisture as the fuel are operating successfully with each of these drying schemes. Pulverized fuel burning is also successfully employed on brown coal and peat in other parts of the world. Processes and techniques for drying the low-rank coals to any predetermined moisture content are well developed and are available in any capacity.

17. The coal-burning gas turbine offers another route by which the low-rank coals can be used for power generation. Extensive pilot plant research is being conducted in several laboratories on the development of this technique. The coal-burning gas turbine will be able to generate power with the consumption of far less water than is required for the conventional thermal-electric plant, a feature of tremendous importance in arid areas. It should be kept in

mind, however, that the coal-burning gas turbine is still in the process of development. The main problem yet to be solved is the development of a unit that will perform for long periods of time between outages for other than routine maintenance. The research being conducted in this field should prove productive, and it is believed that an extremely reliable unit will be developed. When this is an accomplished fact, it will be possible to make a rational economic analysis of the application of the coal-burning turbine for a particular installation. It should be pointed out that factors other than the savings in water are of significance in the selection of power generating equipment.

18. New developments in the transportation of energy may influence the location of coal-burning thermal-electric plants and the economics of their operation. While these developments will probably be discussed in detail by the specialists on power generation, it is felt that attention should be called to suggested techniques that could extend the economical utilization of coal. These include pipeline transportation of coal-in-water or coal-in-oil slurries, improved and more efficient equipment and procedures for rail transportation of coal, and extra high voltage (over 400 KV ac or about 375 KV dc) transmission of power. The cost of delivering the coal to the power plant and of delivering power to the distribution center are significant factors in determining the economic position of coal-burning thermal-electric plants.

19. In many parts of the world, coal historically was the main source of railroad fuel. In recent years it has been supplanted to a large extent by diesel fuel. This change in fuel supply has been dictated almost entirely by economic reasons. In those countries having adequate reserves of cheap, low-rank fuels, and where coal can be produced at a lower energy cost than diesel fuel, a definite area of application for railroad use exists. Because of the properties of low-rank coals, it is usually unsatisfactory to charge raw high-moisture coal to the firebox of a locomotive. With the high temperature and high draft conditions found in the firebox, the high-moisture coals break down into small particles and a large percentage of the fuel is lost up the stack. This obviously presents serious problems of economy and nuisance. It has been found, however, that briquets made from such coal are very satisfactory for railroad use. The type of briquet used is determined by the properties of the coal. For example, some high-moisture coals can be partially dried to 10- to 16-percent moisture content and briquetted without binder. Such briquets are excellent fuel. For this application it is not necessary to produce a smokeless briquet as was the case for domestic cooking, because the draft conditions in the firebox will burn most of the volatile matter. If a binder is required, satisfactory briquets for railroad use can be made by briquetting the dried or carbonized coal with a pitch or asphaltic binder. When such briquets are charged into the firebox, the hydrocarbon binder decomposes and forms a coke matrix, binding the coal fines into a lump-like structure.

20. Low-rank coals can be used in a variety of special industrial applications. Possibly the most significant of these to the less developed areas is the use of such fuels for cement burning. In order to efficiently burn cement clinker, it is necessary to develop a temperature of at least 3,000° F (1,650° C) in the kiln. Because of the heat required to evaporate water from high-moisture low-rank coals, it is not possible to develop the necessary temperature with these coals unless costly and complicated air preheating devices are used. If these coals, however, are dried before being pulverized and charged to the burner in the kiln, a flame temperature high enough to burn clinker can be obtained. This technique permits the substitution of low-rank coal for higher-rank coal or other

fuels for this very important application. The drying of coal in the large quantities required for cement burning can be accomplished economically, in existing equipment. The upgrading of low-rank fuels for cement burning and other industrial applications requiring high temperature could well prove to be one of the most significant uses of the high-moisture coals in the less developed areas. Extraction of montan wax and the production of low-ash material suitable for carbon electrode manufacture are among the possible minor industrial applications of selected low-rank coals having the right chemical properties.

21. It is well known that any rank of coal can serve as the basis for the production of a variety of organic chemicals. Coal supplies the necessary building blocks of carbon and hydrogen, and these can be formed into practically any synthetic organic compound. Carbonization, hydrogenation, gasification, and catalytic treatment are some of the major techniques used. The possibilities for such treatment are only mentioned within the context of this paper. Economic analyses have demonstrated that the production of chemicals by these techniques is competitive only when conducted on a very large scale. Such analyses have shown conclusively that there must be almost complete utilization of the fuel and of the byproducts in order to be economically attractive. Both of these considerations require that a well developed industrial complex be established in order to use the quantity and variety of products that must be produced if such chemical processing is to be economical. By definition, the less developed areas do not yet have such complexes. I believe that it is premature to consider specific chemicals that can be made from the low-rank coals, but some of the major types of products that can be made from these fuels are solvents, protective coatings for pipe, rubber plasticizers, phenolic compounds for plastic manufacture, dye stuffs, fertilizers, and pharmaceuticals.

22. There are, however, two general areas of chemical utilization of the coal that might be considered; namely, synthetic liquid fuel and fertilizer production. Synthetic liquid fuels can be produced by complete hydrogenation of coal at high pressure and temperature and with suitable catalysts, or by the catalytic conversion of "synthesis gas", a mixture of carbon monoxide and hydrogen, obtained from the controlled gasification of the coal. The general use of these techniques for producing liquid fuels is well known, although specific application to any given coal would have to be studied through laboratory investigations. Each of these processing schemes results in relatively complete conversion of the coal. Low-rank coal may be carbonized in an entrained or fluidized carbonizer to produce tar for hydrogenation to liquid fuels. The difficulty, however, with this process is that about 65 percent of the potential heat in the coal remains in the char residue and uses must be found for this fuel. Large quantities of char will be produced and must be consumed if an economically sized plant is constructed. The major application for the char in large quantity would be for power generation, since char is an excellent fuel and can be efficiently utilized in properly designed power plants. It should be kept in mind, that if this latter application is considered, a large power generating industry is required to maintain a balance in the utilization of the two major products.

23. Nitrogen-containing fertilizers are of extreme importance to the less developed areas of the world. Atmospheric nitrogen is fixed by combining it with hydrogen at elevated temperatures and pressures. Low-rank coals provide a source of the hydrogen through either carbonization or gasification.

Carbonization requires that uses be found for the char and tar produced concurrently with the hydrogen and again an integrated, balanced, industrial complex is necessary. Gasification, on the other hand, results in reasonably complete conversion of the coal to hydrogen and carbon monoxide, and these two products can be readily separated. The carbon monoxide can be utilized as a low quality gaseous fuel even if no specific chemical application is available. Fluidized techniques are attractive for gasification, but conventional vertical shaft retorts using the briquetted fuel will probably prove more economical for carbonization. Fertilizer production must be conducted on a large scale to be economical, and large quantities of power are required. Such an industry should, therefore, be integrated with an adequate power generating installation.

24. Naturally oxidized lignites, such as leonardite, can be used as soil conditioners. They contain large percentages of naturally produced humates that are beneficial to the soil because of their ability to hold water and loosen the soil. Oxidized lignite generally occurs as outcrops or in beds under shallow, porous cover. The natural process of oxidation occurring over long periods of time can be approximated by chemical oxidation. Humates can then be extracted from the converted coal, or the entire mass of oxidized materials can be used as a soil conditioner. Oxidized coals, because of the water holding power of the humates, are being used as additives to mud used in well drilling.

25. Any of the low-rank coals can be used for general industrial heating. They can be handfired or charged with a variety of mechanical stokers such as underfeed, traveling grate, or spreader. For such purposes it is not necessary to preprocess the coal, although care must be taken in selecting equipment designed to handle the type of ash found in the particular coal. For example, if the ash in a given coal has a high fusion temperature, the coal cannot be used in equipment requiring clinkering of the ash, and accordingly, a low-fusion ash coal must be used in equipment providing for clinker removal. Most handfired units require lump material, but the fines can be briquetted as described before to make lumplike material suitable for handfiring.

26. Specialty carbons can be made from a wide variety of the low-rank coals, particularly those with low ash contents. Some uses, such as electrodes for electrochemical applications, would not be of immediate interest in the less developed areas. The use of activated carbon produced from low-rank coals for water purification could be profitable. It is possible to convert lignite and other high-moisture coals to excellent activated carbons by carbonization in simple devices. For example, such carbons have been made in large quantity in externally heated rotary kilns, with no byproduct recovery.

27. Storage is a very important factor in the utilization of low-rank (high-moisture) coals. These coals become extremely reactive as they lose moisture. As the moisture evaporates from the capillaries in the coal, new internal surfaces are produced. In addition, the coal slacks or crumbles, also creating new surfaces. These new surfaces are extremely reactive, and any appreciable lot of low-rank coals merely heaped on the ground is susceptible to spontaneous combustion. This tendency towards firing has been a deterrent to the large scale use of low-rank coals in many parts of the world. Storage is important because it is usually not possible to integrate mining and transportation of coal with utilization in order to prevent the necessity for storage. For example, climatic conditions may make it necessary for mining to be practiced only during a portion of the year. It may be too cold or too wet to operate the mines and to transport the coal during some seasons. If the coal cannot be properly stored, usually at point of use, it becomes necessary to restrict

coal use to those industries operated on a seasonal basis. Seasonal operation would not be attractive to the power industry, where production is required throughout the year.

28. As mentioned earlier, the difficulty in storing low-rank coals arises from the drying of the coal and its subsequent oxidation and heating. This heat escapes slowly and the temperature rises, increasing both the rate of drying and the rate of oxidation. This spiral continues until the coal pile ignites. The proper technique of storage, therefore, is one which will prevent these effects. The best approach is to build the pile in layers. The coal is spread in a layer to reduce size segregation and is packed to a high bulk density before the next layer is formed. By increasing the bulk density of the coal in the pile, circulation of air through the pile is minimized. This technique has proven more effective than either ventilating the piles or covering them with thin layers of sealing materials. The packing technique has proven effective on large storage piles, each containing as much as 1,000,000 tons of lignite. Another deterrent to the stocking of high-moisture coals is their tendency to freeze in the cars when they are shipped by rail in extremely cold weather. When this occurs, it is necessary to break up the coal or thaw it before the car can be unloaded. It has recently been demonstrated that freezing can be prevented by mixing a relatively small proportion of thermally dried coal with raw coal before loading.

29. The logical assignment of coals for specific uses requires at least some testing or research. It is to this phase of coal utilization that I would like to direct a few remarks. I have observed that in some areas where there is little or no experience in coal utilization, the need for pretesting the coal to establish its properties and amenability to a specific use has not been recognized. It cannot be emphasized too strongly that even though we speak of coals in terms of large classes, each coal has certain individual characteristics that cannot be predicted. It is necessary in our present state of knowledge to treat such coals as individuals and to determine their specific capabilities. It is certainly possible for an experienced coal technician to block out the general areas of application from only a cursory examination, perhaps by only a visual examination, but selection of the specific equipment and optimum operating conditions requires testing and analysis of the coal.

30. If it is accepted that some competent examination of the coal should be made before utilization processes are finalized, the question arises as to how and where such studies should be made. Laboratory and research facilities should be established in each coal producing country, but it is necessary that selected local personnel be trained in a country having an established coal industry and adequate research facilities. This training can then be utilized in the orderly establishment of the local research facilities. Parallel to this training of laboratory personnel, specific initial coal utilization problems of the less developed area should be studied in existing laboratories in the more developed areas. By obtaining research data and design suggestions from established industrial countries, coal production and utilization can be initiated in an efficient and reasonable manner. The existence of even a nucleus of a coal industry then provides the impetus for the development of the local laboratory and research facilities. It is very difficult to maintain continued interest and support in a laboratory being established in a country without the support of an operating industry in the same field.

31. A realistic approach to coal research must be maintained in development of the new facilities. The distinction must be recognized between fundamental and applied research, and the proper distribution of effort made in the research organization between these two lines. I believe that the most effective approach to the establishment of a coal research organization is to emphasize studies on applied technology. If the local laboratory can demonstrate the application of an existing technique or the development of a new technique that will result in production and utilization of a local coal, continuing financial and political support for this laboratory will be easier to obtain; the laboratory can then expand its fundamental studies.

ANNEX I

TABLE 1. - Physical and chemical properties of FMC Process and foundry cokes [1]

	Coke from FMC Process	Foundry coke
Shape	Uniform pillow blocks	Random
Size, inches	As desired, up to 3-1/2 x 4	Random, up to 4 x 8
Moisture, percent	1-2	1-2
Drop shatter index	92 +	92 +
Tumbler index	92 +	92 +
Crushing resistance, psi	3,000-6,000 [2]	2,000-4,000 [3]
Apparent specific gravity	1.0-1.05	0.95
True specific gravity	1.95	1.95
Bulk density, lb ft^{-3}	38-42	28-32
Proximate analysis, moisture-free basis, percent:	[4]	[4]
Volatile matter	2-3	1-2
Fixed carbon	92-95	88-93
Ash	3-6	5-10
Sulfur	0.5-0.8	0.5-1.0

[1] Data supplied by the FMC Corporation, New York, N.Y., U.S.A.

[2] Based on cylinders of one-square-inch cross sectional area.

[3] Based on 1/2-inch cubes.

[4] Analyses shown are typical. Actual values depend upon ash and sulfur content of the coal used.

1572 E - Nov.1962 - 1,600